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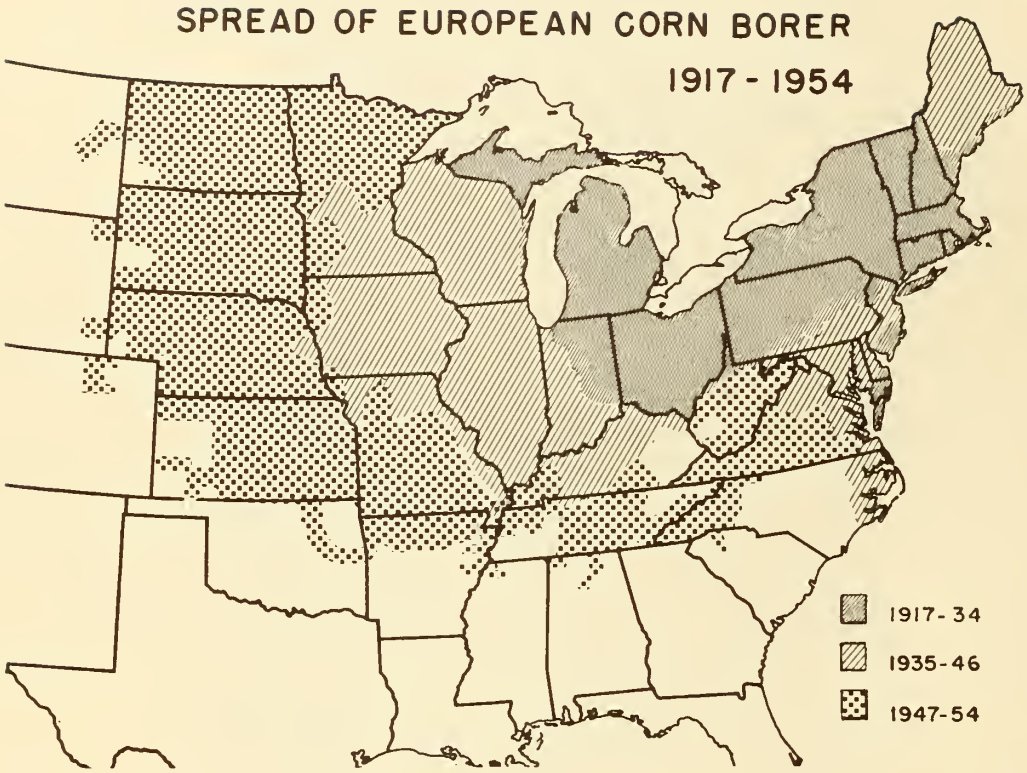
A Situation Report

THE EUROPEAN CORN BORER

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE



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THE EUROPEAN CORN BORER is one of the most threatening and destructive pests of corn in the United States. Damage done by this insect in 1954 is estimated to have prevented the development and harvesting of 192 million bushels of corn, worth $261 million -- about 7 percent of the national crop. Hardest hit were the Corn Belt States of Illinois, Iowa, Nebraska, and South Dakota.

Annual borer abundance counts made by State agencies in the fall of 1954 indicated that, if weather favored the insect, Corn Belt farmers would be faced with another heavy infestation during the growing season of 1955.

An additional 18 counties in 6 States were invaded by the borer in 1954. The insect is now known to exist in 1,596 counties of 37 States -- every State east of the Rockies except Florida, Louisiana, and Texas, as well as eastern Colorado, Montana, and Wyoming.

The worst year for corn borer damage was 1949. Had it not been for the injury inflicted by the borer, an estimated 314 million bushels more of corn would have been harvested that year, worth nearly $350 million.

The threat of the corn borer can be met. Control measures have not prevented its spread from New England to the Rocky Mountain States, but effective control is possible and heavy losses can be avoided, even in years of heavy infestation.

HISTORICAL AND DESCRIPTIVE

THE FIRST corn borers that entered the United States were apparently stowaways, in broom corn from Hungary or Italy. They probably arrived between 1909 and 1914. When the national door was closed on imported plant pests with passage of the quarantine inspection law in 1913, the borer was already here, though it was not discovered until 1917. It was then causing severe damage to sweet corn in the area of Boston, Mass., and had reached areas around Schenectady and Silver Creek, N.Y., and St. Thomas, Ontario, Canada.

By 1934, the borer was known to exist in 125 counties of 11 States -- Connecticut, Indiana, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, and Vermont. Continuing an uneven spread year after year, the pest had reached into 953 counties of 28 States by 1946. Ten years later, in 1954, it was present in three-fourths of the States and in more than half of the counties of the

United States. Over a 16-year period (1939-54) the borer spread, on the average, into 70 new counties each year. In the 37 years since its discovery in Massachusetts, the borer has spread westward about 1,700 airline miles into eastern Montana, Wyoming, and Colorado; northward about 350 airline miles throughout New England; and southward some 600 airline miles into northern South Carolina, Georgia, Alabama, Mississippi, Arkansas, and Oklahoma. (See map for general picture of the borer's spread from 1917 to 1954.)

Factors favoring its spread are: (1) Strong flight of adult moths (they can fly at least 20 miles, rest on either land or water, and take off again); (2) abundant host material in the path of the advance; (3) no mountain barriers in the Lakes and Plains States; (4) tenacity of survival of borer larvae in cornstalks; (5) the use of more than 200 species of grains, weeds, vegetables, and flowers as alternate hosts or sheltering places; (6) weather conditions advantageous to the insect; and (7) the increase in numbers of borers that produce two or more broods in a growing season. The latter two factors are probably most important.

Like many insects, the European corn borer (Pyrausta nubilalis) has four stages of development -- the egg; the larva or caterpillar stage; the pupa or resting stage; and the moth or adult stage. The borer passes the winter as a full-grown brownish or pinkish larva, normally in a cornstalk but also in various plant debris. It changes to a brown pupa about mid-May, and the yellowish or brownish moth emerges from late May to early July. Soon after emergence and mating, the first-brood female begins to lay her eggs, from late May to early July. The eggs are deposited in irregular white clusters about one-fourth of an inch across, usually on the underside of corn leaves. The eggs overlap one another like fish scales. Each female moth lays from 400 to 500 eggs, deposited in clusters of 15 to 25. The eggs hatch in 5 to 7 days and the young larvae emerge. There is a high mortality in young larvae, but the borer has such a high birth rate that it can continue to increase even if survival of the brood is as low as 2 percent.

The larva is the destructive stage, the greater part of which is spent inside the cornstalk, where it cannot be reached by most control methods. That is why timing is so important in the use of insecticides, to catch the larvae while they are still outside the plant. Young larvae of the first brood feed in the whorl of the corn plant and in the leaf sheath and midrib, and may do enough damage to cause an appreciable reduction in yield. But most damage is done by older first-brood larvae after they bore into stalks and ears, from late July to late August. Borer larva go through five stages (or instars) of growth, molting between each instar. The full-grown larva is about three-fourths of an inch long. The borer working inside the cornstalk destroys the plant's food channels, causing starvation and incomplete development of ears, weakens stalks and ear shanks, and by means of its tunnels opens the way for the entrance and development of stalk rots and other diseases. Borer attack thus causes poor ear development, broken stalks, dropped ears, higher harvesting costs, and lower yields.

Eggs of the second brood, coming from moths developed in the first, are laid between late July and early September, the larvae appear from early August to late October, and the heaviest damage of this brood is done to maturing corn in September, October, and November.

As the borer moves south, additional broods may be expected because of the longer growing season. A third brood has occurred in southern Virginia and in North Carolina, and a partial third brood has appeared in some parts of the Corn Belt. As many as nine broods a year are known in a tropical climate like that of the Philippines. Since the borer has thus far penetrated only into the northern edges of the southern tier of States, there has been little experience to indicate what will happen there in the production of multiple broods.

FOUR-WAY CONTROL

NO SINGLE METHOD of controlling the European corn borer has been completely effective. There are four ways, however, of combating this persistent and costly pest. One is recommended cultural practices on the farm. A second is the use of insecticides, properly timed and properly applied. A third is the release of borer parasites by State and Federal governments. And, finally, there is the growing of corn that shows resistance to the borer.

It is impossible to assign to these control methods any relative degree of importance. Each is important, each has a fluctuating value from one year to the next, and all should be used within feasible economic limits. One thing is certain -- the weather is a major factor in the abundance of the corn borer in any particular year. Overwintering of larvae is important. Ordinarily about 10 percent survive the winter. When 17 percent came through the winter of 1953-54 in the Corn Belt, it forecast a heavy infestation during the growing season of 1954.

Farm Practices

Research has shown that some farm practices reduce the number of overwintering larvae, and others do not. Furthermore, activity designed to reduce the number should be approached on a community-wide basis. Infested cornstalks and cobs left above ground on one farm can result in adults moths flying to adjacent fields and to fields for miles around to lay thousands of eggs.

RECOMMENDED (if practical for the area and not in violation of soil conservation practices):

Feeding infested plants to livestock as silage or fodder. When corn is used as ensilage, borers that escape destruction in silage cutters die later in the silo. When fodder is run through cutting, shredding, or husk-

ing machines, a high percentage of borers is killed. Most larvae not killed in these machines die in the course of storage, feeding, and use of the shredded material as bedding. Finally, the tramping of stalks and fragments into animal manure destroys remaining larvae.

Plowing under corn and weed remnants. Deep plowing -- 6 inches if possible -- while it does not destroy all larvae, leaves those that survive and crawl to the surface an easy prey to weather and natural enemies. Deep plowing should also be clean plowing -- leaving no stalk and weed fragments above ground to provide a refuge for larvae. Plowing may be done either in fall or spring. Spring plowing is preferred, especially where there is danger of wind or water erosion and, of course, where standing stalks are left as winter feed for livestock or as cover for wild life.

Planting according to local experience. Planting should not be too early or too late. Early-planted corn is most attractive to egg-laying moths of the first brood. The first brood does the most damage, to succulent and immature plants. Late planting may result in losing part of the growing season, lowering the vitality of the plant, and reducing the yield. Late-planted corn is attractive to egg-laying moths of the second brood and is most likely to be heavily infested late in the season. The best advice is: Plant corn at the time that results in the best yield.

NOT recommended:

Burning of cornstalks; it destroys organic matter needed in the soil and permits borers to survive in stalks not completely burned.

Disking corn stubble to sow oats or wheat; disking kills only a few of the borer larvae. A crop rotation should be recommended that involves plowing after a corn crop.

Use of mechanical stalk choppers to beat up stalks in picked fields; these devices kill no more borers than disking.

Rolling and soil packing; they have no practical effect on borer control.

Insecticides

Timed right and put on right, DDT is an effective weapon against the corn borer. Ryania also gives satisfactory results. Parathion and EPN have shown promise in tests, but they are deadly poisons and are not recommended for general use.

Timing includes preplanning in order to have the insecticide available if it is needed. County agents can assist farmers in advance of the season.

Treatment of field corn is usually profitable if there are more than 50 egg clusters per 100 plants or if 75 percent of the plants show leaf feeding. When only one treatment is planned, it should be made 10 to 14 days after the first egg hatch (the schedule can be varied to meet State or local knowledge of the situation).

Proper application depends on previously considered decisions as to the use of dust or sprays, the use of high- or low-gallonage sprays, whether to buy or rent ground spraying or dusting equipment (it may not be available unless early arrangements are made), whether to contract for aerial application, the adjustment of nozzles for the most effective distribution of the insecticide, whether to plan for one or more treatments of the crop, and so on. One treatment is usually sufficient for field corn, unless the infestation is very heavy, but sweet corn for canning or the market and seed corn should have three to four well-timed applications.

DDT is usually applied in sprays at the rate of 1.5 pounds of the insecticide to the acre, diluted in 5 to 50 gallons of water. Dusts are normally applied at the rate of 2 pounds of DDT (20 pounds of 10- or 40 pounds of 5-percent dust) or 30 to 40 pounds of 40-percent ryania per acre. If two treatments are planned, the second should be applied 7 to 10 days after the first. If the second brood of the borer appears at the rate of 100 egg clusters per 100 plants, another treatment is justified for this brood. State and county agricultural agents can give the best on-the-ground advice in these circumstances.

It should be borne in mind that corn plants treated with DDT should not be fed to dairy animals or to animals being finished for slaughter.

A granular type of insecticide is being studied (see below), but it has not yet been perfected to the satisfaction of State and Federal scientists.

Parasites and Predators

Since 1930 the United States Department of Agriculture, cooperating with various States, has released about 11 million fly and small wasp parasites of the corn borer in corn-growing areas to assist in control of this pest. These parasites are descended from those originally imported from Europe or the Orient. In more recent years many of them have been transplanted from eastern areas of the United States to those farther west. Larvae of the parasites feed on the corn borers and destroy them. The use of parasites is the only means found thus far of attacking borer larvae within the plant.

Of some 20 species of parasites, 5 have become widely established. Techniques had to be developed for this work not only for choosing effective parasites abroad but also for shipping them to the United States, increasing the supply, reshipping them, releasing them in the field, and later making surveys to determine their usefulness.

It is impossible to measure statistically what effect these parasites have had in checking the corn borer. They have been useful, as evidenced by data obtained in surveys. But their usefulness varies from year to year -- they also are subject to environmental conditions. For example, in one area of Iowa the number of borers parasitized rose from 1 out of 100 in 1944 to 1 out of 3 in 1947, decreased to 1 out of 4 in 1949, and rose to a high of 2 out of 3 in 1950.

Distribution of parasites by State and Federal agencies continues.

In addition to introduced parasites, the borer is attacked by many natural enemies throughout its life. Lady beetles and other insect and mite predators feed on the egg clusters. Birds, ants, wasps, rodents, and predaceous insects eat the larvae. Downy woodpeckers and some other birds dig full-grown borers out of cornstalks as part of their winter diet. These predators help to whittle down the borer population. But, in spite of all the natural and artificial means of destroying borers, the insect continues to survive due mainly to its high reproductive capacity and to the fact that it spends so much of its time hidden in the corn plant where few natural enemies can reach it.

Use of Resistant Strains

Observation has shown that there are important differences in the number of borers that survive on different strains of corn. The strains that show resistance to the borer are being studied and crossed (see below) in a program designed to produce corn hybrids that are resistant to the borer and at the same time have the many other qualities needed in corn to make a good crop.

No hybrids that are immune to the European corn borer have yet been developed and made available commercially, but some with resistant qualities have been developed and are recommended for use in certain areas. Several hybrids have been released by State agricultural experiment stations that have effective resistance to first-brood borers as well as the ability to stand up well and produce good yields when infested by the second brood. County agents can provide information on currently known hybrids with these qualities.

THE OUTLOOK

SINCE 1917, when the European corn borer was first found in the United States, research has been furnishing the facts about this pest. By observation, scientists have learned the life history of the insect, an essential step in finding its vulnerable stages. More scientists have joined the battle as the borer spread to additional States. In carefully controlled experiments, research men worked out the four methods currently available for attacking the borer.

Investigation continues along many lines. Some approaches have been tried and found unpromising. They may be picked up and tried later, in the light of further knowledge. The effort is always to find ways to control the insect and to minimize the results of its attacks, by economic methods that can be adapted to normal farm practice. Two of the most promising lines of current research are aimed at finding and developing plant resistance and a more effective insecticide.

Breeding Resistant Plants

Plant breeders seeking to develop good-quality corn that is resistant to the corn borer encounter many complexities, and the many questions that can be asked are by no means all answered.

The quality of resistance in a plant to the attacks of an insect, for instance, is a peculiar thing, and the best-informed scientists are not yet able to explain it fully. On highly resistant corn, young larvae die within 4 days in much larger numbers than on susceptible corn. On resistant strains the surviving larvae develop more slowly and are smaller than those on susceptible strains, suggesting that they have a nutritional deficiency. Feeding on resistant corn also slows down and sometimes reduces pupa formation, thereby delaying the appearance of second brood moths and reducing their number. This effect on pupa formation is important, for when summer pupation is sufficiently reduced there is little difficulty with second-brood infestation.

Whatever the facts may turn out to be about plant resistance, this quality has promise as an additional weapon against the borer. The goal, of course, is to develop desirable corn inbreds that are so lethal -- or lacking in nutrition -- that very few larvae can survive on them.

The mortality of young larvae of the first brood is high in any case. Even on corn that is not resistant, 60 to 70 percent may die on the first day after hatching. Another 10 percent are gone by the fifth day. In 30 days only about 5 percent are left. Corn can be graded for its degree of resistance within 10 days after the first brood hatches.

Entomologists and plant breeders speak of plant resistance primarily in relation to the first brood of borers. On whorl-stage corn the establishment of first-brood borers is markedly different from that of the second brood when the corn has tasseled. A study has been made to determine the favored feeding positions on different strains of corn of each of the five stages or instars of larvae in both first and second broods. In the first brood, before corn tassels, three-fourths of the first-instar larvae and more than half of the second-instar larvae feed on the leaf in the whorl where they are closely associated with surface moisture. Most larvae of the third and fourth instars prefer the leaf sheath, although about an equal number of the fourth instar remain in the whorl or on the tassel after it emerges. Ear injury and stalk invasion generally await develop-

ment of the fifth instar or full-grown larvae, which then live in relative security and plenty inside the stalk, ear shank, and ear. One promising thing about resistance is that different strains of corn have different resistance factors that affect different instars of larvae. This gives rise to the hope that by combining these resistance factors it may be possible to develop inbred strains that carry resistance factors against most if not all stages of larvae.

For the second brood, plant breeders seek mainly plant tolerance to the borer. The corn plant has now completed most of its vegetative growth, it has tassels, silks, and pollen, and the ear is in various stages of development. Pollen is shed all over the plant but accumulates particularly in leaf sheaths and young ear shoots. The pollen and the silks provide food for the young larvae of the second brood, which have a higher survival rate -- yet ordinarily do less damage -- than those of the first. Young second-brood larvae feed largely on exterior ear structures that do not control the flow of nutrients to the ear. Thus the yield may be substantially fixed before fifth-instar larvae begin their inroads into the stalk and ear shanks, paving the way for rots to weaken the plant further. The principal damage done by the second brood is to cause stalk breakage and ear dropping. Mechanical pickers have difficulty in harvesting corn from broken stalks, which adds to the expense of harvesting. Broken stalks also clog the pickers and lead to picker accidents.

The aims of researchers are therefore to seek out and develop hybrids that are resistant to the first brood and tolerant of the second, the quality of tolerance being expressed by good standing ability and little ear dropping.

On the surface, plant breeders working on resistant and tolerant corn have an embarrassment of riches. Resistant lines of corn can be found in many open-pollinated or special synthetic varieties. Geneticists say that they could produce hundreds of resistant lines in a year -- far more than could be evaluated for yield and other desirable characteristics. Some lines are resistant to first brood attacks but not tolerant of stalk rots. Some lines have both resistance and tolerance but the resistance is not high. Furthermore, many lines prove resistant to the borer but do not have good vigor, high yield of good sound grain, are not resistant to smuts and rots, show no resistance to such pests as rootworms, aphids, earworms, and other insects. Resistance, tolerance, vigor, high yield, good standing ability, and power to withstand a host of pests and diseases are all needed. Plant breeders find that they must constantly compromise in their selections of inbreds for producing generally suitable hybrids. The requirements of hybrids vary widely in different parts of the United States.

Some of the best borer resistance found so far traces back to Lancaster Surecrop corn, an old variety from Pennsylvania. Other resistant lines come from old varieties formerly grown in other parts of the United States. Very little of the resistant material now being used came from

abroad. These lines of corn must be bred together, and at least three -- maybe four -- resistant inbred lines must be combined into a hybrid to obtain the qualities required. The work is highly technical and takes a great deal of time. Geneticists and entomologists teamed up on this work about 1942 and several years of work will still be needed before a wide selection of hybrids with effective resistance and tolerance can be released.

The question arises as to whether resistance in a plant has any deleterious effect when the plant is fed to livestock. While the final answer may not have been obtained, it is reassuring to know that fairly resistant hybrids have been fed to animals as silage, fodder, and grain over a period of years without any observed ill effects.

Another bothersome question, not yet answerable by scientific test, brings forth a hypothetical reply. The question: Will borers become tolerant to resistant types of corn in much the same way that some insects become tolerant of DDT? The answer: Yes, it may be expected, though resistance seems to be a stable quality -- one strain has been observed to maintain a certain amount of resistance for about 30 years. But, when and if borers develop tolerance to resistant plants derived from American strains, it may be possible to introduce foreign strains to offset the tolerance. Furthermore, if we can combine several resistance factors in hybrids that are effective against most or all stages of borer larvae, there will be little or no opportunity for the insect to develop tolerance.

As to the future, "We are confident that hybrids with greater corn-borer resistance can be developed and will appear in increasing numbers in 4 or 5 years." Two of the leading plant geneticists in the U.S. Department of Agriculture made this prediction. The work may go faster or slower, depending on this paradoxical situation:

Bad years of borer infestation will hasten the work, years of light infestation will retard it. If there is a series of "bad" years, the work will progress faster because there will be plenty of borers to work on the lines of corn being tested. A series of years of light infestation or poor survival of larvae on manually infested plants might result in inconclusive tests and necessitate retesting.

"In this work," said one of the plant breeders, "you need patience and optimism."

Granular Insecticides

Cooperative experimentation in 1953 and 1954 by the Iowa Agricultural Experiment Station and the Agricultural Research Service indicates that granular formulations of certain insecticides, of about the same consistency as granulated sugar, may be more effective than sprays in controlling the corn borer. The granules tend to adhere temporarily to the leaves and then roll into the moist whorls and leaf sheaths, where young larvae prefer to feed.

Best results in application of the insecticides were obtained by a grass-seeder modified for the purpose. Existing power dusters were ineffective because of their inability to handle the larger-sized particles satisfactorily. If in the course of further tests the granules continue to show excellent borer control, equipment for applying them on a commercial basis will need to be developed.

The best one-application control was obtained in these tests by applying the granules at or just after the peak number of corn borer eggs had hatched.

Second-brood borers were reduced by as much as 90 percent by the use of granules. Application at the time of pollen-shedding gave the best control of second-brood borers, but more work is needed on placing the insecticide for this brood.

One of the most favorable aspects of granular-type materials is that they leave very little deposit of insecticide on the plants. Cattle and hogs are often pastured on corn fodder left in the fields after picking. Especially with DDT, there is a potential hazard if too much insecticide is left on the plant, for the chemical tends to deposit in the body fat and may be excreted in milk. With the use of granules, far less DDT is left on the plants than with emulsion sprays.

Another year or two of testing may be needed to establish the proper application and use of granular material, but appearances are hopeful.

Diseases of the Borer

Corn borers are "disgustingly healthy" from the standpoint of diseases introduced to prey upon them. Some diseases slow the growth of the borer, but none of sufficiently high virulence has been found to be promising as a control measure.

There is a hope that something may be found that is as effective and practical as the milky spore disease which is used to combat the Japanese beetle. This is a continuing field of investigation.

Systemic Insecticides

The new field of systemic insecticides -- those that are taken in by the plant and circulate in the sap -- is a hopeful one in combating an insect pest that spends so much of its life inside the plant itself.

Work with systemics to control the European corn borer has so far been limited. One systemic insecticide placed in the soil to reach the roots of young corn plants was absorbed by the plants. Newly hatched corn borer larva were placed daily on pieces of foliage from the treated plants. All of the young larvae were killed even on leaves sampled 18 days after

treatment. Other tests have shown toxic or repellent action to the European corn borer of corn plants grown in soil treated with several compounds.

The case is not closed on systemic insecticides as a means of borer control. The method remains open as a promising field of research.

SUMMARY

NUMEROUS ATTEMPTS have been made by scientists to find a vulnerable stage in the life cycle of the corn borer that would permit destruction or effective control of the pest by means readily available to governmental agencies and the farmer. The problem has been and remains a baffling one. The following thumbnail summary, by life stages of the borer, shows that attempts have been made to attack every stage, but none has yet provided consistent and satisfactory control under all circumstances.

Egg. -- Natural enemies that feed on borer eggs include the lady beetle and other insect and mite predators. Some introduced parasites attack egg clusters. Native and introduced organisms with a taste for borer eggs, although they assist control, have never made sufficient inroads on the supply to substantially affect the borer population. The egg clusters are protected by a waxy substance and no material has been found that will penetrate it and not at the same time damage the corn plant.

Larva. -- This is the "soft underbelly" of the corn borer, the only stage at which it has thus far been possible to combat the pest with any degree of success. Insecticides, plant resistance, parasites, and cultural practices are aimed almost entirely at larvae. Each succeeds to a point. Introduced diseases, should sufficiently destructive ones be found, would also probably attack the larval stage. Yet with all this, the larva remains the stage most destructive to plants, causing all the damage chargeable to the borer.

Pupa. -- Except for the effect of resistant strains in inhibiting pupa formation, apparently no control device reaches the pupa stage.

Moth. -- Poison bait and light traps have been tried, with very limited success. They are not considered practical under field conditions.

BORER FORECASTING

UNCONTROLLED WEATHER remains the principal factor governing incidence of the borer in any given year. The specific weather factors favoring the borer have not yet been sufficiently determined to make them useful in forecasting heavy infestations. As weather in relation to the borer

is further studied, and as long-range weather forecasting improves, it may eventually be possible to give advance warning of control steps to be taken.

The annual fall borer census, as matters now stand, is the best forecast warning service available. Ordinarily carried out after mid-September by cooperating States, the fall census indicates the abundance of the pest. The use of standard spot-check survey techniques makes the census data meaningful for the entire infested area. Abundance is expressed as the number of borers per 100 corn plants.

The survey data are released to the public late in January or early in February. The 1954 report of the census, for instance, was issued in the January 28, 1955, issue of the Cooperative Economic Insect Report, a weekly publication of the Agricultural Research Service. The report shows infestation by States and counties. It showed that large areas of central Iowa, northeastern Nebraska, and southeastern South Dakota, and several counties in central Illinois had heavy infestations in excess of 500 borers per 100 stalks. In these areas of heavy infestation, the warning is clear that, if conditions were favorable for overwintering of larva, a heavy infestation might be expected the following growing season. In some States and counties, spring surveys are undertaken to determine the number of overwintering borers, and warnings are issued when overwintering is heavy. Throughout the growing season, State officials are constantly on the watch for occurrence of the borer in areas not previously infested.

Farmers and those who advise farmers should take advantage of every known means of controlling the borer, especially in areas of heavy infestation.

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